Pennsylvania Regional Infrastructure Project

Presentation by:

The Concurrent Technologies Corporation (CTC) Team

January 6, 2004

Presentation Outline

- Introduction of CTC Team
- CTC Background
- Technical Approach
 - CTC Team Member Presentations
- Conclusions

The CTC Project Team



Hydrogen Separation Hydrogen Sensors



Tradeoff Analyses of Hydrogen Delivery Approaches



Composite Material Development and Prototyping

CTC - Team Lead

- CTC specializes in providing technologybased solutions
 - Independent nonprofit
 - Applied research and development professional services organization
 - Staff of over 1,300 professionals
 - Approximately 900,000 sq. ft. of office, laboratory, and demonstration factory space
 - Operates from 34 locations throughout the U.S.
 - First nonprofit research and development organization to simultaneously register to both the ISO 9001 and ISO 14001 international standards
 - Federally compliant contractor

Scope of CTC

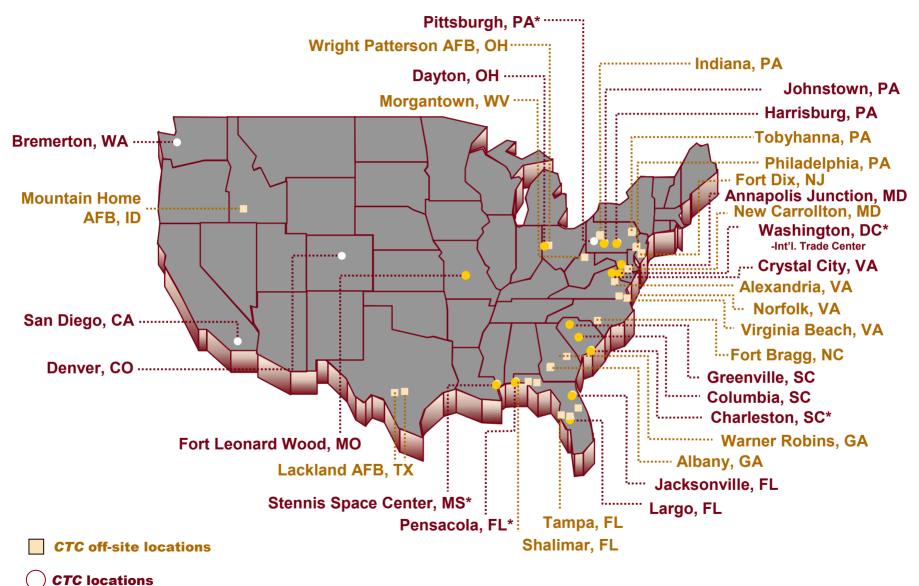
- Product/process development and transition to commercial practice
 - Through application of appropriate science and engineering
 - In a concurrent engineering framework
 - Within economic and regulatory constraints
 - Facilitated by electronic commerce and networking
 - Reinforced by education and training at all levels

Selected Services and Capabilities

- Advanced Coating Development
- Advanced Distributed Learning
- Advanced Materials and Processes
- C4ISR Systems
- Fuel Cell Test and Evaluation
- Information Systems Security
- ISO 9000 and 14000 Training and Consultation Services
- Life-Cycle Optimization
- Logistics Optimization
- Manufacturing Improvement
- Modeling and Simulation

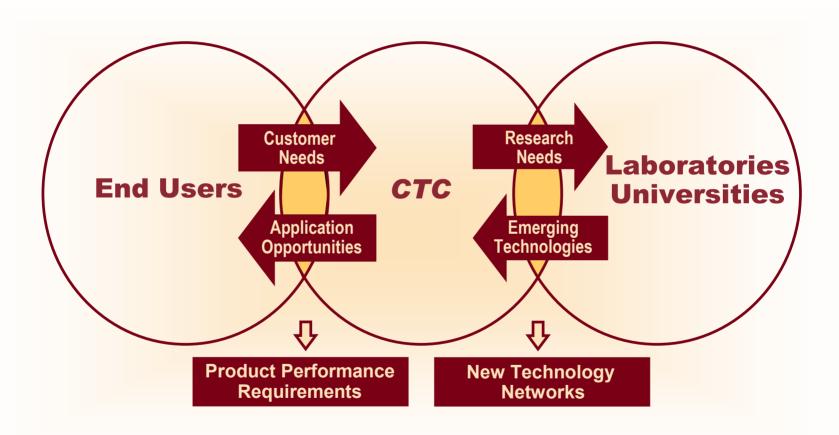
- Network Security
- State-of-the-Art Systems Design and Analysis
- Supply Chain Management
- Sustainability
- Systems/Software Engineering
- Systems Integration
- Technology Assessments
- Technology Demonstration and Validation
- Threat Assessment, Reduction, and Mitigation
- Visualization

CTC Locations



^{*} CTC location and CTC off-site location

Technology Transition





CTC Puts Ideas into Action

Converting an Army Vehicle to Hybrid-Electric Power





CTC designed and developed a Hybrid Electric-High Mobility Multipurpose Wheeled Vehicle (HE-HMMWV) that achieves 20.9 miles per gallon (mpg) as compared to 7.1 mpg for current U.S. Army M1097 conventionally powered vehicles.

CTC Puts Ideas into Action Fuel Cell Test and Evaluation Center (FCTec)

- Established in 1998 Operated by CTC
- Technology & Vendor Neutral
- Recognized as a National Resource for 3rd Party RDT&E
- Utilized by Government, Developers, and End Users
- 35,000+ Sq. Ft. Fuel Cell and Fuel Processor Test Areas
 - Thermal Load Banks (Up to 250 kW)
 - Variety of Gas/Liquid Fuels
 - Resistive and Inductive Electrical Load Banks
 - 1 W 550 kW
 - Fuel, Gas, and Water Analysis Systems
 - Evaluation of Fuel Cell Flow Streams
 - Variable Environmental Conditions
 - Environmental and Altitude Chambers
 - Shock and Vibration System
 - Home Simulator System
 - Grid Simulator System
 - **■** EMI Test Chamber



CTC Puts Ideas into Action

■ These and hundreds of other success stories are strong testimony to clients' confidence in and satisfaction with *CTC*.

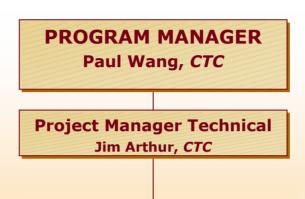








Task Structure



Hydrogen Delivery <u>Eileen Schmura, CTC</u>

- ■Determine feasibility of cotransporting hydrogen and natural gas in existing pipelines
- Determine feasibility of separating hydrogen from hydrogen/natural gas blends at the point of use
- ■Tradeoff analysis to determine the best hydrogen delivery approach(es) in Pennsylvania

Material Development Bob Dax and Hao Dong, CTC

■Construct prototype materials for pipelines and gas storage tanks

Hydrogen Sensor Development

Lonnie O'Baker, CTC

- Develop hydrogen-specific sensors
 - Determine % level H₂ in feed gas
 - Determine ppm level H₂
 for leaks

CTC Key Personnel

Paul Wang, Program Manager

- Over 13 years experience with managing DOE Programs
- Previously served as DOE Field Program Coordinator

Jim Arthur, Project Manager

- Leading many projects for commercial and DoD clients
- Led development of chemical processes for many DoD/industrial applications

Eileen Schmura, Hydrogen Delivery Lead

- Served as Technical Lead for CTC's Fuel Cell Program
- Over 20 years experience in energy and environmental engineering activities

Bob Dax, Material Development Co-Lead

- Led the Titanium Metal Matrix Composite Fabrication Program and the Concept Exploration for The Joint-Unmanned Combat Air Systems Program for the Navy
- Technical Program Manager for the DOE Verification and Validation Program

Dr. Hao Dong, Material Development Co-Lead

- Over 40 years experience in teaching, research, and industrial problem solving in metallurgy
- Principal team member, task leader, or project manager for diverse government and commercial projects.

Lonnie O'Baker, Hydrogen Sensor Development Lead

- Sr. Engineer of the Power and Electronics Group
- Responsible for control system, data acquisition system, PLC, and HMI design and programming.

Technical Approach General

- Perform Baseline Assessments
 - Gather information
 - Organize, catalogue and inventory
 - Analyze and evaluate information
- Summarize Finding
 - Identify specific R&D needs
 - Develop technical plans for completing R&D

- Assessment of existing natural gas pipeline materials and operational characteristics
- Computational analysis of co-transport of flow
- Technology for separation of hydrogen and natural gas
- Economic trade-off study (RDC)

- Document materials of construction used in the existing natural gas pipelines, under varying operating conditions
 - Feed gas chemical composition
 - Pressure
 - Temperature
 - Flow Rate
 - Ambient conditions

- Computational analysis of co-transport of flow
 - Obtain gas thermodynamic and transport properties
 - Conduct CFD computations to
 - » Analyze potential separation of hydrogen from mixture
 - » Understand 3-D distribution of H2 inside pipes (flow velocities, concentrations, partial pressures, etc.) and how piping layout would affect hydrogen distribution in mixture
 - Design an experimental plan for refinement and validation of computational analysis results
 - Apply the refined tools to determine the Limit of vol. %
 H2 that can be co-transported in existing pipelines

- Technology for separation of hydrogen and natural gas
- Examine various delivery scenarios and determine their effects on the selection of separation technology (-ies)
- Assess available separation technologies
 - Membranes/ ultrafiltration/ nanofiltration
 - Absorption techniques
 - Adsorption, including PSA
 - Cryogenics/ others
- Determine suitability of each technology for H2/ NG separation and identify technology gaps/ R&D opportunities

Material Development

- Target hybrid structures for pipelines and storage tanks
 - Coatings
 - Composites
 - Metals
- Identify and/or develop test methods for monolithic and hybrid structures
- Meet operational requirements (high strength, high pressure, etc.) for hydrogen pipeline transport and compressed gas storage
- Develop life prediction and survivability models
- Address lowering manufacturing costs, including body in plant components
 - Durability
 - Welding and joining
 - Surface finish and coatings

Technical Approach Material Development

- Assess and suggest materials (metallic alloys, composites) for pipelines and compressed storage tanks based on available results
- Investigate surface treating/coatings/linings for existing pipelines and storage tanks
- Perform modeling and analyses to study effects of permeation, induced stress, and operational/environmental conditions
- Develop testing approaches and methods

Targeted Metallic Alloys

- Aluminum
- Austenitic Stainless Steels (> 7% Nickel)
- Carbon Steels
- Copper
- Titanium

Targeted Composites

- Build on findings from a recent CTC article on implementation of composite materials on military assets, Advanced Materials and Processes, September 2004
 - Manufacturability
 - Mechanical properties
 - Environmental considerations
 - Costs of procurement, joining and repair

Targeted Surface Finishing and Coatings

- Kel-F
- Teflon
- Tefzel
- Kynar
- Viton
- Buna-N
- Neoprene

Application of Lifing and Survivability Models to Identified Materials

- Perform statistical analyses to determine lifing characteristics and survivability of materials
- Modify as needed for different classes of material (pipeline steel, composite pressure vessel, coatings, etc.)
- Include test excursions for effects of material dimension and directional stresses, and test environment
- Apply refined models to a select material, make prediction on performance and aging behavior

Testing Methods

- Coordinate tests with life prediction models
- Conduct high-pressure testing to obtain data on:
 - Hydrogen embrittlement
 - Hydrogen permeation
 - Fracture toughness
 - Cracking and corrosion
 - Fatigue crack growth
- Establish procedures for testing hybrid structures

Technical Approach Hydrogen Sensors

- Independent assessment of available and developmental sensing technologies for Hydrogen detection
 - > Optical
 - Catalytic Bead
 - > Microcantilever
 - Metal Oxide
 - > Carbon Nanotube
 - > Electrochemical Detection
 - Palladium H2 Absorption Technology

Identify R&D needs from assessment

- Where are the technology gaps
- > What are the shortcomings of current R&D efforts
- > What requirements are increasing R&D efforts

Technical Approach Hydrogen Sensors

- Establish capability of hydrogen-specific sensors to determine percent-level hydrogen in feed-gas (including hydrogen/natural gas blends) and ppmlevel hydrogen for leaks
- Targeted sensor applications for hydrogen delivery and storage
 - External sensing
 - > Intrinsic sensing
- Coordinate and collaborate with Air Products to develop and test prototype hydrogen sensors

PRODUCTS 4—Y

Pennsylvania Regional Infrastructure Project:

Hydrogen Separation and Sensor Development

Dr. Robert N. Miller Air Products and Chemicals

Hydrogen Pipeline R&D Project Review Meeting January 5-6, 2005 Oak Ridge National Laboratory, Oak Ridge, TN

Today's Presentation

- Air Products and the Hydrogen Economy
- Technology Capabilities
 - **Gas Separation Technology**
 - Sensors
- Project Team
- Project Scope
 - Hydrogen Separation R&D
 - Hydrogen Sensor Development

Air Products – World leader in industrial hydrogen

- Largest merchant hydrogen producer over 50% share
- Operate over 60 plants Americas, Europe, Asia
- Produce over 1.25 million tonnes per year
- 7 H₂ pipeline systems around the world (over 350 miles)
- 6 liquid H₂ facilities
- Supply H₂ purification equipment condition (cryogenic, PSA, membranes)



HyCO Pipelines Serving the World . . .

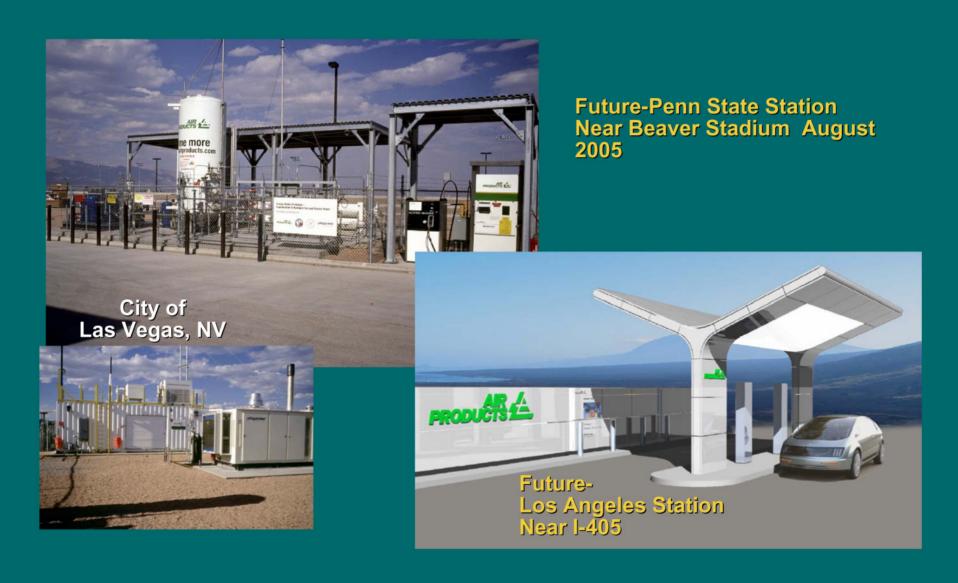


Air Products' future energy solutions for the hydrogen economy

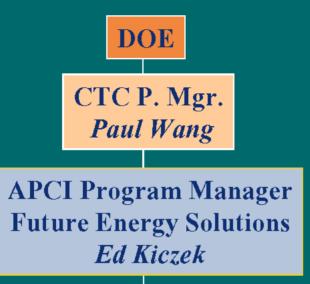
- Demonstration leader
 - 30+ fueling stations, PSA purifiers,
 mobile fuelers
- Developing solutions for the H₂ economy sourcing, on-site generation, storage, delivery, safety systems and infrastructure
- Global safety leader
 - Codes & standards team
 - KnowH₂owSM safety training



Hydrogen Fuel Stations



Air Products Project Team for CTC Pa. Regional Infrastructure Project



Government
Contracting
R. N. Miller, Marketing
Pat Alba, Contract Admin.

SENSOR DEVELOPMENT TASK

Frank K. Schweighardt, Co-PI
Tech. Support:

David Zatko and Jean Baldwin

SEPARATION DEVELOPMENT TASK

Jim Occhialini, Co-PI

Tech Support:
Ed Weist and Tim Golden

Air Products' Separation Capabilities

- Gas Separation is a Core Competency
- Recovery/Purification
 - Adsorption PSA and VSA
 PSA pressure swing adsorption
 VSA vacuum swing adsorption
 - Hollow Fiber Membrane
 - Absorption
 - Cryogenic
 - Catalytic
 - Ceramic Membranes (ITMs)



Adsorption Products

- World's Broadest Portfolio of Pressure, Vacuum, and Temperature Swing Adsorption Products
 - Nitrogen PSA & Oxygen VSA
 - Hydrogen PSA
 - Air Drying and CO2 Removal (TSA, PSA)
 - Synthesis Gas Drying (TSA)
 - Carbon Dioxide VSA
 - Carbon Monoxide VSA
 - Natural Gas Treating (TSA, VSA)
 - Helium Purification (PSA)
 - Heavy Hydrocarbon, Sulfur, Chloride Removal (TSA)
 - Cryogenic Adsorption

Adsorption: A Strategic Technology Complete Capability

- Basic R&D in Adsorbents
 - Composition of matter discoveries
 - Modification of commercial adsorbents
 - Leverage multiple material vendors to optimize



- Simulation Capability
- Lab Capability
- Plant Testing Capability



- Optimization of many variables for customer-specific requests
- Innovate along all dimensions
- Flexibility in product packaging
- Operations and Integration Experience
 - Feedback plant data into scale-up and design
 - Ongoing maintenance knowledge for critical components









Successful History of H2 PSA

- H2 PSA is an Important APCI Technology
 - Systems deployed since 1986
 - >100 Units Built and Operated
 - <0.1 MMSCFD to >150 MMSCFD
 - Demonstrated up to 99.9999% H2 Purity
 - Systems available from vacuum to >35 barg
- Broad Experience in Reformates and Feed stocks
 - All types of reforming: SMR, ATR, POX, EHTR, Secondary Reforming (Air/O2)
 - Multiple Feed stocks: off-gases, natural gas, propane, naphtha, methanol, biomass
- Major Development Program Underway for distributed H2 applications

H2 PSA Development Goals



Conventional 1 MMSCFD







Fully Operational



In Test

Gen 3

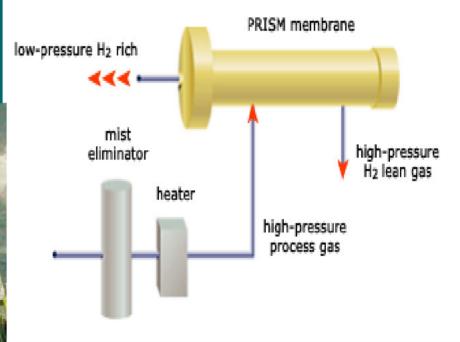


In Design

Prism Membranes

PRISM® membrane systems are engineered, designed and fabricated by the Air Products at its St. Louis manufacturing facility.





Prism Membranes Benefits:

- Economical recovery of hydrogen.
- Can operate at high process loop pressures such as 2500 psig.
- Robust against plant upsets.
- Small skid footprints.
- No moving parts means minimal maintenance costs.
- Easy to install and operate.

High-purity separation of H₂ from natural gas for pipeline delivery infrastructure

Performance requirements:

- Pipeline co-transport of H2 and natural gas.
- Point of use purity requirement: >99.995% H₂
 with less than 10 ppm CO, preferably less than 2 ppm CO.
- Targeted performance: H₂ recovery efficiency >80%

High-purity separation of H2 from natural gas for pipeline delivery infrastructure

Project Scope

- Assess technical and economic feasibility of available separation technologies (adsorption vs membranes).
- Variables to be considered:
 - -- Feed composition (% hydrogen)
 - -- Feed pressure
 - -- Point of use flow rate
 - -- Product (hydrogen) purity
 - -- Product delivery pressure
 - -- Separation cycle time and efficiency

High-purity separation of H2 from natural gas for pipeline delivery infrastructure

Project Deliverables

- A go/no-go decision in September 2005 to proceed with the chosen separation technology for further experimental/modeling study.
- A report on comparative analysis of separation technologies (3/2006)
- A report on the conceptual poof of principle design of a separation technology with established technical and preliminary cost feasibility (3/2006) in readiness for a field test (beyond the scope of this SOO).

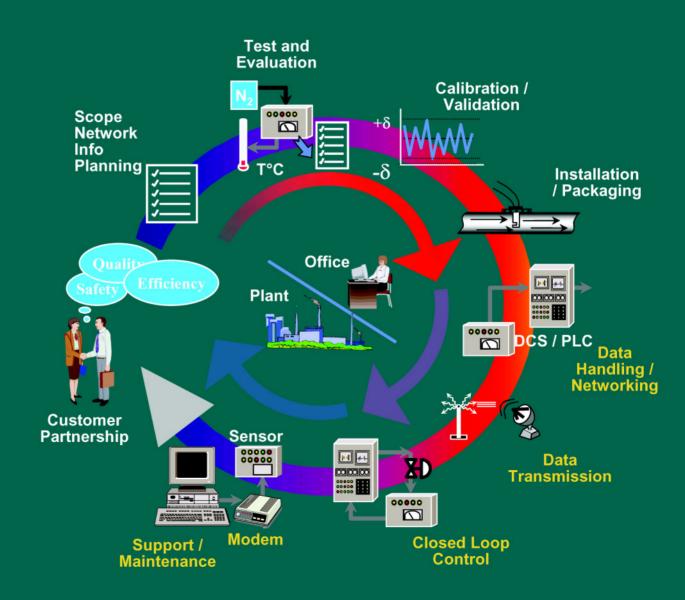
Strong Capability in Process Analytical Technology

- In-plant sensor development
- Remote monitoring (eRAM)
- Analytical problem solving for gases and chemical plant applications
- Process and product improvement and cost reduction via deployment of analytical protocols
- Extensive laboratory and testing facilities in Allentown, Pa.
- Extensive Collaboration with Sensor
 Development and Mfg. Companies e.g.



Sensor Implementation Process Cycle

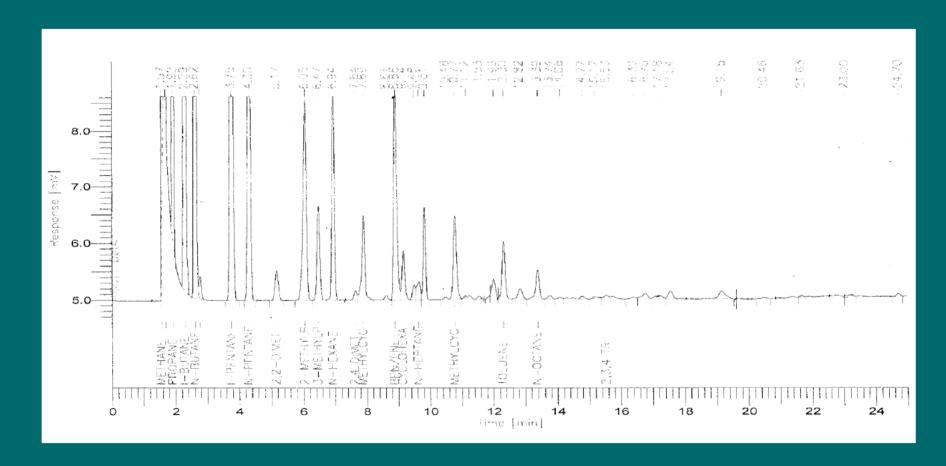
Air Products uses a systematic multifaceted process to develop a sensor or analytical method for field applications.



Critical steps

- Nurturing mfg. production by finding the limitations
- Testing in real-world environments (i.e., contamination)
- Testing the application (natural gas pipeline) outside!
- Testing robustness
- Planning for remote monitoring

Awareness of Complexities (contamination) that may affect sensor performance

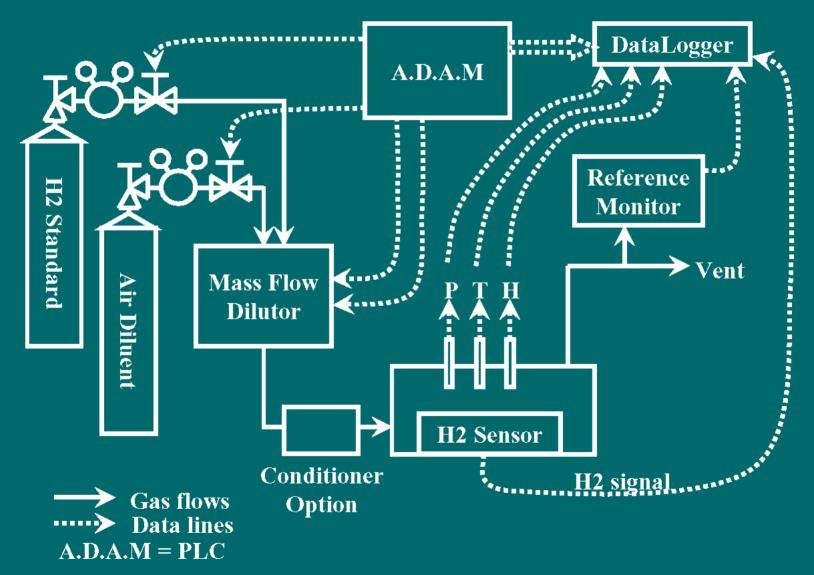


Natural Gas (from a major NG user in PA)

Potential Monitoring Locations for Hydrogen Sensing in NG/H₂ Pipeline Scenario

- Valves, flanges, relief valves, cracks created by H2 embrittlement (if any)
- Old NG pipe and new NG pipe
- H2 transfer (transfer lines and storage containers)
- H2 managed environments (near H2 storage tanks / along transfer lines / within personnel zones / around any combustion zones)

Laboratory Testing Set-up for H₂ Sensors



Current H₂ Sensor Technology Under Evaluation at Air Products

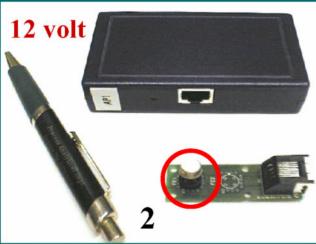
Basic Detection Range: Leak: 50 - 50,000 PPMv (5%)

LEL = 40,000 PPMv (4%)

H₂-Specific Candidate Technologies (pre-production):

- 1. Palladium alloy thick films resistance
- 2. Palladium alloy thin films resistance/voltage
- 3. Nano-technology resistance/voltage







Evaluation of H₂ Specific Sensors for Leak Detection in H₂ + Natural Gas Pipelines

Performance Requirements:

Select promising technologies that meet the defined specifications and configurations below:

Table	1 A	Sne	cifica	itions	of	H2	sensor
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Table 1A Specifications of fiz sensor							
Parameter	Level	Units					
Component specificity	H_2	-					
Oxygen requirement	not required	-					
Operating range	0.01 - 5	%					
Chemical interference							
CO	>0.5	ppmv					
H2S	>0.01	ppmv					
Humidity	5% - dewpoint	-					
VOC (diesel exhaust)	>10 ppmv	-					
Precision	+/- 5	%					
Calibration drift (short)	< 2.5 (24 hrs)	%					
Calibration drift (long)	<10 (3	%					
	months)						
Electrical	noise < 100	ppmv					
Response time	< 2	sec					
(> 10 % change)							
Full range	< 5	sec					
(0.1-5%)-time-constant							

Table 1B Sensor configuration

Set-up	Range	Units
Ambient temperature range	-40 -160	° F
Ambient pressure range	0.8 - 1.2	atm
Calibration/validation	One point	-
requirement	NIST-Ref	
Sensor size (w/electronics)	2x2x1	inches
Alarm levels		
(if process required)		
Level l	10,000	ppmv
Level 2	20,000	ppmv
Level 3	30,000	ppmv
Level 4	40,000	ppmv
Level 5	50,000	ppmv
Sensor-to-electronics	< 6	feet
distance		

Evaluation of H₂ Specific Sensors for Leak Detection in H₂ + Natural Gas Pipelines

Project Scope

- Assess current commercial and developmental H2 sensor technologies and select promising ones that meet defined requirements.
- Further develop, test, and evaluate H2 sensors for the pipeline application.
- Evaluate performance under the operating environments in air, methane, and natural gas, and study the effects of contaminants (e.g., sulfur), temperature, pressure, and humidity.
- Develop in-field calibration and maintenance and remote monitoring capability.
- Compare the concept of incorporating H2-sensing mechanisms into new wall materials for pipelines and gas storage tanks against external application of sensors (i.e., attached to the pipelines and tank walls.)

Evaluation of H₂ Specific Sensors for Leak Detection in H₂ + Natural Gas Pipelines

Deliverables

 A summary report on demonstration results of 3 sensor systems operating for 1-3 months in a natural gas environment (9/2005).

Lab testing data of 3+ H2-specific sensors

Field testing data of those sensors

Ranking of each sensor feature based on data

Prospectus of improvements by manufacturers

Testing protocols for NG field environments

Long term and field condition protocols

A go/no-go decision will be made in September 2005 on whether to proceed to the follow-up work (not part of this SOO) for a field-scale demonstration. A selected "best" sensor for deployment



-The CTC Team —













506 Billy Mitchell Road Salt Lake City, Utah (801) 537-1800

Fiber Science History

- Founded 1967: Gardena, California
 - Design & Development
 - Filament Wound Water Tanks
 - Layup
- Among the "Pioneers" in Fiberglass composites for aircraft applications
- Purchased by EDO Corp. in 1971, moved to SLC







Fiber Science Today

- 103,000 SF Composites facility
- 70 Employees Over 1/2 in Production
- Advanced Composite Design, Development, Fabrication
- Focus: Long Term Relationships







Core Competencies

- Composite Design and Development
 - design for "Producibility" (efficient and repeatable)
 - design to cost and performance
 - internal R&D programs
- Precision Filament Winding (wet/prepreg)
 - lowest-cost fabrication methods
 - repeatable and accurate
- Advanced Composite Lay-up
 - aircraft/space grade structures
 - precise, complex, optimum performance

Manufacturing Processes

- Filament Winding
- Hand Lay-up
- Vacuum assist RTM, VARTM
- Autoclave and Oven Cure
- Prototype and Production Fabrication
- Materials
 - Vinyl, Polyester, Epoxy, BMI
 - Carbon, Fiberglass, Kevlar®, Spectra®
 - Thermoplastics

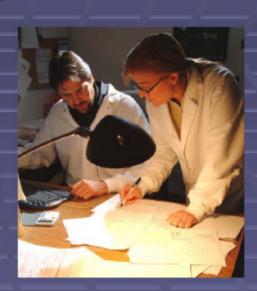






Engineering

- Design Tools
 - CATIA, UniGraphics, SolidWorks, AutoCad
 - solid modeling
 - FiberSim
 - Ply book, flat pattern, laser-ply projection
 - Composite Pro, Laminator
 - Laminated Plate Theory
 - Orthotropic and Isotropic Material
- Analysis Tools
 - Finite Element
 - NASTRAN, COSMOS/M
 - Linear, Non-linear
 - Fatigue, Dynamic





Quality Assurance

- ISO 9001 Certified
- Boeing D6-82479 Audited and Approved
- Boeing "Gold-Rated" and "Straight to Stock" Supplier
- Mil-Q-9858A , Mil-I-45208, Mil-Std-45662
- ASQC Certified Level III Quality Engineer
- Two on-site FAA-DMIRs
- Hold several FAA-PMAs



In-house Testing

- Material
 - incoming verification, re-certifications
- In-process
- Qualification
 - planning and reporting
- Final Inspection
 - acceptance and certification









Mechanical Testing at EFS

- Test Sample Fabrication and Testing
 - Tensile, Shear, Compression, Impact and Flexure
 - Test Frame for Large Structures
 - Pressure and Vacuum Testing
 - Physical Properties
 - Laminate Properties
 - Void Content, Fiber and Resin Volume by Acid Digestion or Furnace Burnout
 - Resin Properties
 - Gel Time and Viscosity





Non-Destructive Examination (NDE)

- In-house NDT-UT and PT Level III Engineer
- A-scan: Dry and Wet Couplant Techniques
- C-scan
 - Immersion Tank for Composite Tubes
 - 5-Axis Automated Inspection Bay 8'x 10'x 4'
 - wet and dry couplant capability
- Mechanical Impedance Analysis: Laminate Bond Testing, Thin Wall and Honeycomb Laminates
 - Liquid Penetrant
 - Radiographic: Working Relationship With Readily Available Level III and Outside Lab



Materials Testing

- Cured Laminate Characteristics
 - Glass Transition Temperature
 - Degree of Polymerization
 - Heat Distortion Temperature
 - Thermal Coefficient of Expansion
 - DSC and TMA Instrumentation
- Chemical Properties
 - Resin/Adhesive Characterization
 - Fourier Transform Infrared Analysis (FTIR)
 - High Performance Liquid Chromatography (HPLC)





Manufacturing Experience

- Aircraft Structures
- Light Weight Storage Tanks
- Missile System Components
- Other Advanced Structures



Filament Wound Products

- Composite Fuel Tanks
 - Design, development, production
 - Thousands
 Manufactured
 - Army, Navy, Air Force









Fiber Science - Summary

- 35 year track-record in composites
- Stable, financially sound company
- Complete engineering development through production capabilities
- Precision lay-up, filament winding, RTM
- ISO 9001 certified
- Fiber Science teams with customers to provide cost-effective solutions

EFS Subcontract Task Summary

- Hydrogen Regional Infrastructure Program in Pennsylvania (H2RIPP)
 - Characterization of existing and new materials for varying pressure regions of hydrogen
 - Pressure
 - Temperature
 - Contaminants
 - Duty cycle
 - Transients
 - External factors such as impact and vibration
 - Deliverables: Month-to-month technical support and a summary report

EFS H² Project - Key Personnel

- Tim Douglas Principal Engineer
 - University of Colorado (M.E.)
 - 21+ years experience; Engineering design and analysis (advanced composites for aerospace and defense applications
 - Co-inventor on one EFS patent; joined EFS 2001
 - Recent project experience:
 - Design and Analysis of Sikorsky Comanche (helicopter)
 Glare Shield
 - Various IR&D projects

- Robin Lawson Design Analyst
 - University of Wisconsin, Madison (Engineering Mechanics and Astronautics)
 - Joined EFS in 2003; 2 years prior experience in composites design (STW Composites)
 - Recent project experience:
 - Sikorsky Comanche HEPA Filter Bracket and Glare Shield design and vibration analysis
 - Water & Waste tank (production program) support

- Elizabeth Davis Design Engineering Lead
 - University of Idaho (M.E., 1986)
 - Designer, Analyst, Team Leader, Technical Project Manager & PI; 15+ years at EFS
 - Design engineer of record for every type of aircraft water and waste tank developed at EFS since 1990
 - Co-inventor on two patents pending
 - Recent project design leader experience:
 - Thick composite pressure vessel study
 - Sikorsky Comanche Cockpit Console
 - Boeing (waste tanks) Impact Resistance program.

- Dan Kennedy Technical Program Manager
 - University of Utah (Mechanical Engineering)
 - 10 yrs experience heavy manufacturing (Eimco, Baker Hughes); Engineering, Tooling Design, QA, Facilities, Manufacturing Management
 - Employed in the composites industry for almost ten years; joined EFS in 1999 in Tech Sales / Program Management
 - Program Manager, Sikorsky Comanche contracts requiring Design, Analysis and Qualification of the components in addition to tooling and manufacture.
 - Co-inventor on numerous issued and pending patents.

- Randy Jones Comm'l & Marine Products
 - Boise State Univ. & CSU Dominguez Hills (Business, Marketing, Aviation Management)
 - Technical marketing of aerospace, commercial and defense-related products and services for nearly 25 years
 - Service at Alcoa, Ciba-Geigy, Puritan Bennett on Planes, Trains & Automobiles, and other stuff
 - Co-author of seven published technical society papers; Co-inventor on five patents and two EDO trademarks



The Resource Dynamics Corporation

- Founded in 1979, RDC has over two decades of experience in assessing new technology and business models in energy markets
- Staff comprised mostly of engineering professionals, many with advanced degrees in business
- Located in Vienna, Virginia with an office in Portland, Oregon
- RDC utilizes an extensive set of tools in their work, including a number of proprietary databases and models to develop project solutions

The CTC Team —

RDC's Four Business Areas Encompass Fuel Distribution Issues

- 1) Strategies for Power and Fuel Suppliers. Helping power and fuel suppliers develop competitive strategies by providing commodity market analyses, organizational and market technology assessments, and fuel procurement strategies.
- 2) Distributed Generation. Assisting companies to position themselves in the marketplace, by evaluating markets, technologies and equipment, potential sites, and feasibility studies.
- 3) Marketing for Energy Businesses. Providing services to help competitive and regulated energy businesses launch new businesses, using RDC's unique customer intelligence and market research.
- 4) Strategies for Energy Purchasers. Assisting businesses in developing and executing competitive energy procurement strategies.

Hydrogen Delivery Tradeoff Study

- The goal of this task is to identify and quantify the most important tradeoffs between alternative hydrogen delivery approaches
 - Using Pennsylvania markets to examine the economic, risk, technology, and public safety tradeoffs
 - Results should suggest most attractive approaches for delivering hydrogen from production facilities to end users
- Three steps to be employed:
 - 1) Data collection
 - 2) Economic analysis
 - 3) Sensitivity analysis

Hydrogen Delivery Tradeoff Study Step 1: Data Collection

- Data will be collected about each of:
 - Pennsylvania MSA's socioeconomic characteristics
 - State chemical plant and petroleum refinery locations
 - Stationary power plant locations, electric transmission and distribution system and any capacity bottlenecks,
 - Natural gas pipeline infrastructure, rail infrastructure, interstate highway system and any hazardous material transport restrictions
 - Other parameters pertinent to delivering hydrogen
 - Additional data will be assembled on hydrogen delivery and intermediate storage costs, drawing from DOE reports, presentations on the topic, and other literature

Hydrogen Delivery Tradeoff Study: Step 2: Economic Life-cycle Analysis

- Quantifies the economic cost of each alternative scenario identified during the first step.
- A set of base assumptions will be developed to establish the capital cost, operating and maintenance costs, and risks associated with each scenario.
- Applying these assumptions, along with a range of interest rates, tax rates, discount rates, and other financial parameters, the net present value of alternative hydrogen delivery scenarios will be computed and compared.

The CTC Team —

Hydrogen Delivery Tradeoff Study: Step 3: Sensitivity Analysis

- Evaluates a set of economic and non-economic tradeoffs including:
 - Energy supply issues, including hydrogen production assumptions
 - Hydrogen storage technology timelines and costs
 - Potential use of intermediate hydrogen storage and delivery facilities
 - Other parameters identified after Step 2 is underway
- The result will be an assessment of key tradeoffs in delivering hydrogen between producers and consumers within Pennsylvania

Project Management System

- Project Management will be conducted using CTC's policies and procedures
 - Established to meet both quality and environmental management standards (ISO 9001 and 14001)
 - » Committed to continuous improvement
 - Tracking key performance measures
 - » On-time performance
 - » Quality planning
 - » Financial performance
 - » Customer satisfaction

Deliverables / Milestones

Milestone/Deliverable	M1	M2	М3	M4	M5	M6	M7	M8	М9	M10	M11	M12	M13	M14	M15	M16	M17	M18
Baseline Technology					4													
Assessments																		
Report on existing natural gas																		
pipeline materials and									-									
associated operational																		
characteristics																		
Hydrogen Delivery Tradeoff																		_
Study																		
Conceptual design of																		
separation technology																		
Comparative Analysis of																		_
Separation Technologies																		
Report on new material																		
development for pipeline												-						
transport and off-board storage												_						
applications																		
Report on new tooling designs																		\rightarrow
for off-board gas storage tanks																		
using new composite materials																		
												-						
Report on demonstraton results																		
of three sensor systems																		
																•		
Quarterly Status Updates																		

The CTC Team —

In Conclusion

- The CTC Team is Committed to:
 - Conduct the project in cooperation with DOE
 - Build upon existing knowledge base